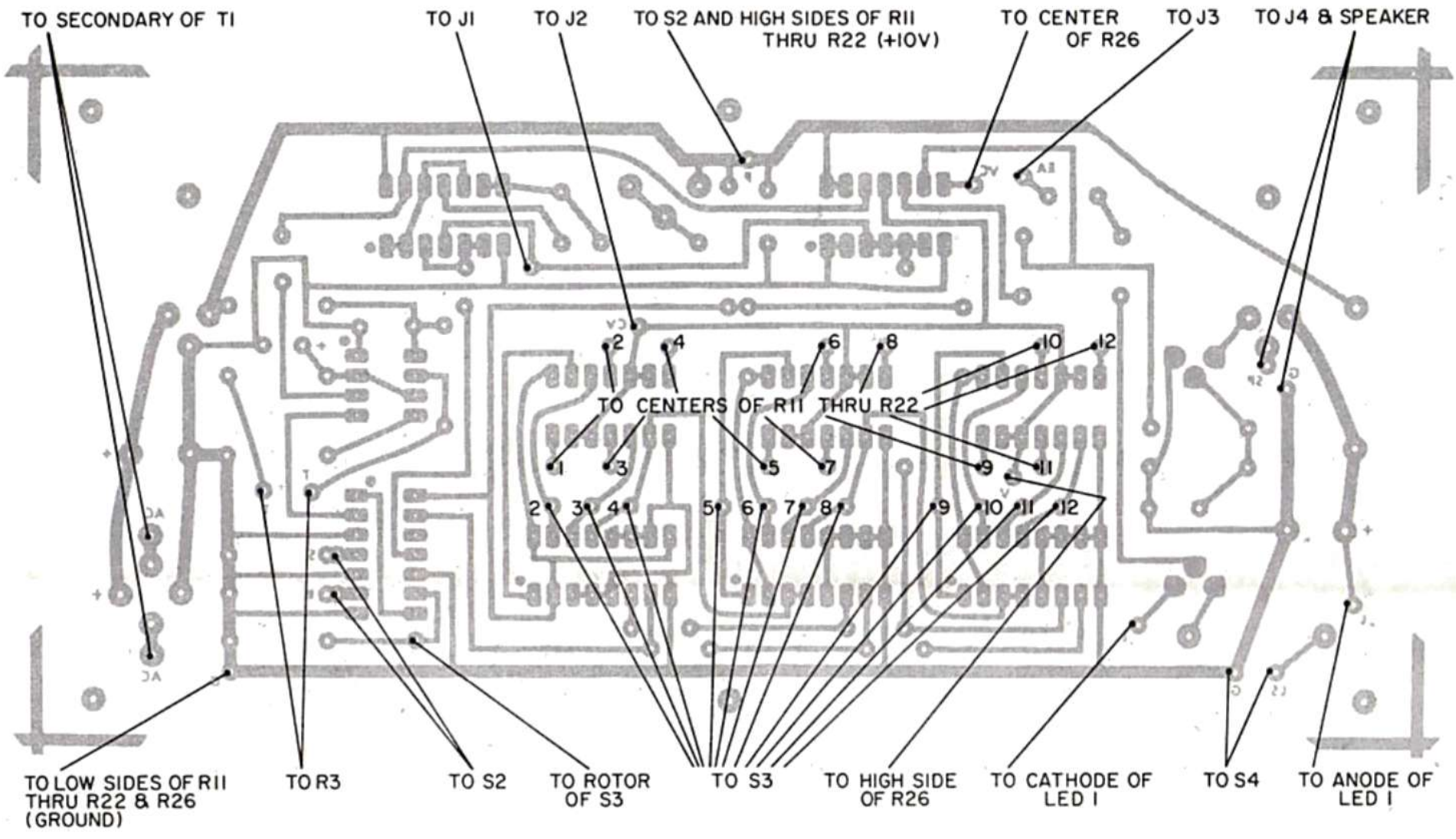
elementary
Electronics
A DAVIS PUBLICATION

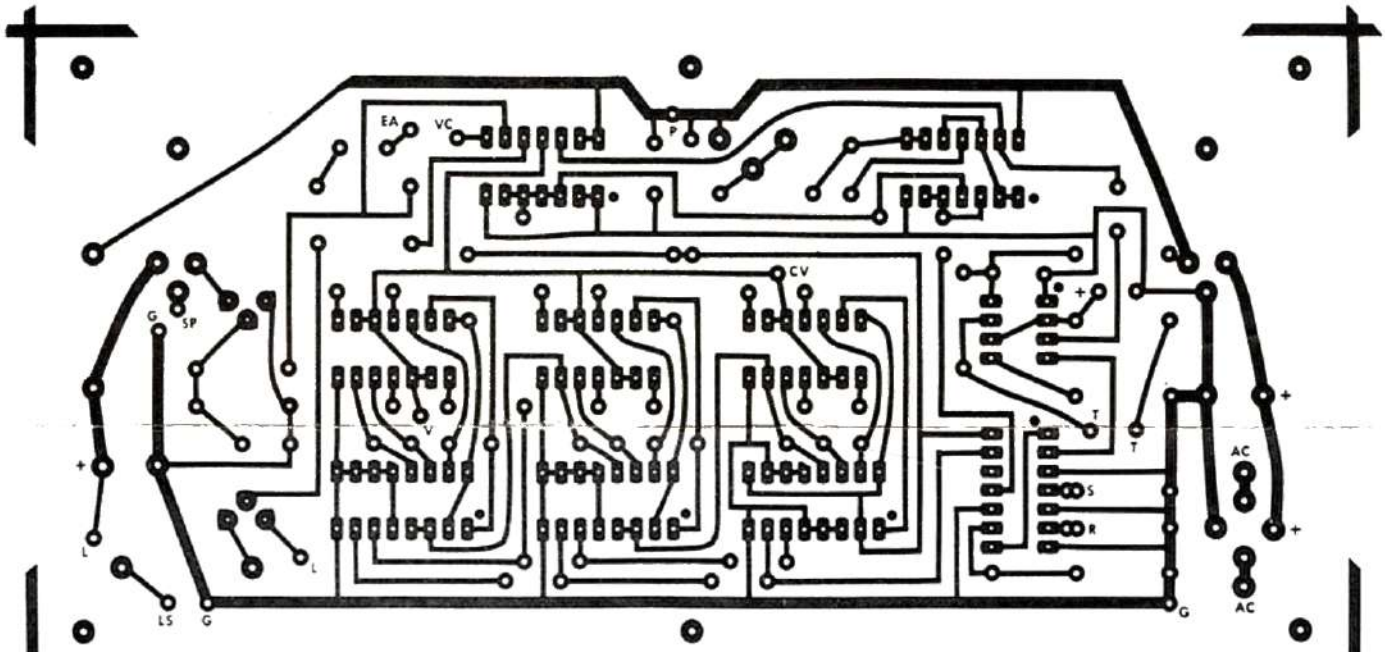
380 LEXINGTON AVENUE • NEW YORK, N.Y. 10017 • 212-557-9100

RHYTHM AND BLUES BOX

Here is your free printed circuit board template, parts location diagram and PC board wiring guide. This will enable you to build the PC board for the "Rhythm and Blues Box" project that appeared in the January/February 1979 issue of ELEMENTARY ELECTRONICS. We hope you enjoy building this terrific little music maker.

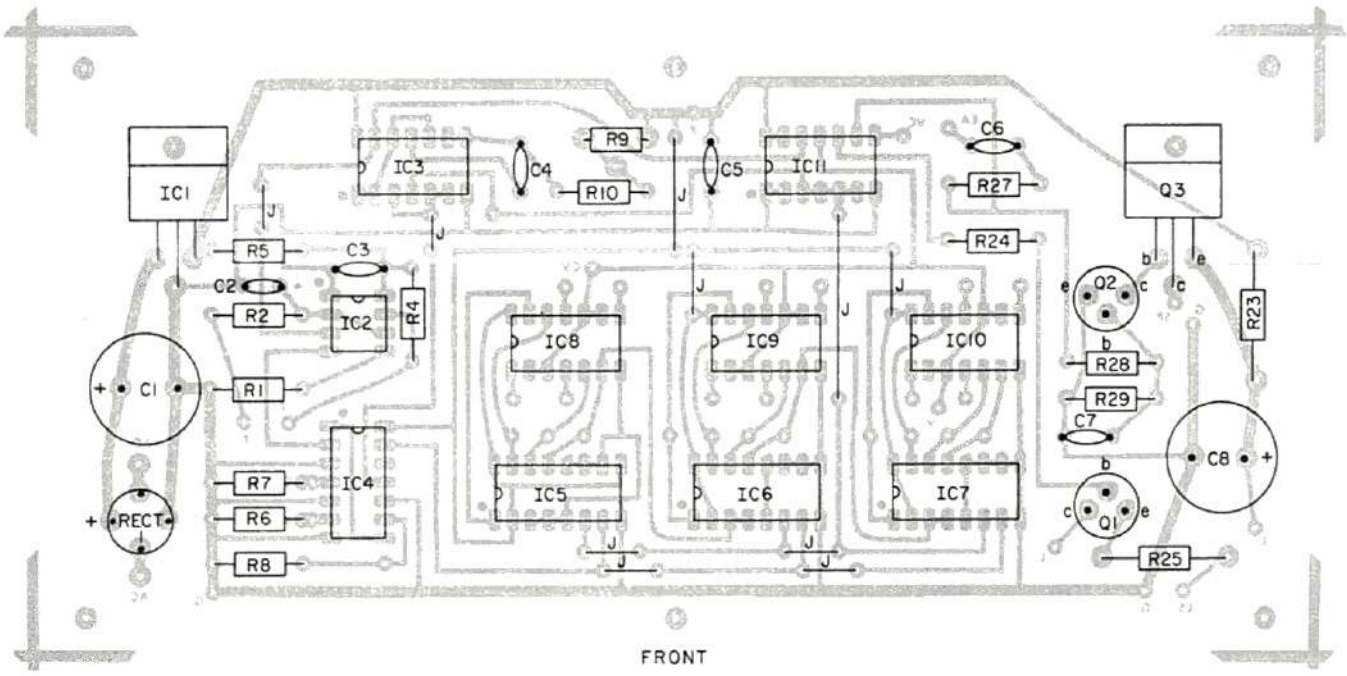

TO SECONDARY OF T1
TO J1
TO J2
TO S2 AND HIGH SIDES OF R11 THRU R22 (+10V)
TO CENTER OF R26
TO J3
TO J4 & SPEAKER
TO CENTERS OF R11 THRU R22
1
2
3
4
5
6
7
8
9
10
11
12
TO LOW SIDES OF R11 THRU R22 & R26 (GROUND)
TO R3
TO S2
TO ROTOR OF S3
TO S3
TO HIGH SIDE OF R26
TO CATHODE OF LED 1
TO S4
TO ANODE OF LED 1

FRONT



FRONT

COPPER SIDE



FRONT

elementary Electronics Jan./Feb. 1979

Rhythm & Blues Box

Boogie to the sound of this electronic drummer

by Randall Kirschman

RHYTHM IS THE TIME-PATTERN of sounds that enables us to distinguish a march from a mazurka, and it is one of music's basic ingredients. It could also earn a stack of votes from both beginner and veteran musician alike as one of the most troublesome. But help can be close at hand if you build the rhythm synthesizer described here.

Use our Rhythm and Blues Box while practicing on an instrument, to analyze or demonstrate rhythms, even for learning dances. It can also be connected to a percussion generator to provide simple accompaniments, or can serve as a programmable controller for music synthesizers. Whatever your particular involvement with rhythm, you will find the R&B Box a valuable companion.

A metronome is the traditional aid for timing in music, but it falls short in the rhythm department because the clicks it produces are all identical. In music, rhythm comes about when each beat does *not* receive identical emphasis. With the R&B Box you can overcome metronomic monotony by giving each click in a sequence a different emphasis to produce musical rhythms.

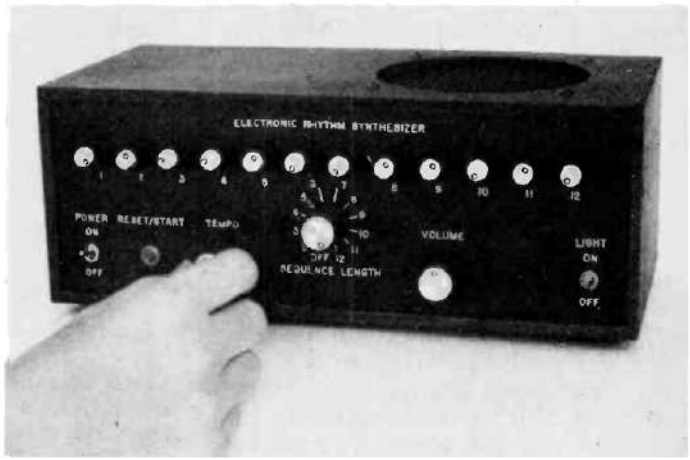
A notable feature of this rhythm synthesizer is that it is not limited to standard or preset rhythms, but can be set up to generate thousands of rhythms of all kinds. Furthermore, each rhythm is precise to the microsecond.

Let's find out how the Rhythm and Blues Box accomplishes its feat by taking a tour of the circuit. Even at second glance the circuit may seem formidable, but it can be understood by tackling it a section at a time. Each section is a basic building block which you may meet in other circuits also—the multivibrator, shift register, flip-flop, latch, analog switch, and multiplexer.

Good Vibes! We'll begin our tour with IC2, a 555 timer, and its associated components. These form an astable (free-running) multivibrator that generates a continuous train of pulses to drive the rest of the circuitry. The pulse rate, which sets the tempo of the rhythm, is controlled by *Tempo* pot R3. The pulses from IC2 (pin 3) go to IC3A. IC3A and IC3B, both NOR gates, are connected as a monostable (one-shot) multivibrator, which puts out a pulse each time it is triggered by a pulse from IC2. This pulse is then fed to NOR gates IC3C and IC3D to improve its shape and to generate both an inverted (negative-going) pulse (from pin 3 of IC3C) and a positive-going pulse (from pin 4 of IC3D). As we'll see, these pulses serve as *clocking* (or simply *clock*) pulses for the flip-flops in the synthesizer. They occur at the same rate as the tempo pulses from IC2, but are narrower.

Shift Into High. The next section on our itinerary is a *shift register*. Basically, a shift register is a string of flip-flops connected in cascade. The output of each flip-flop is connected to the input of the next and all are clocked by the same clock pulse. Thus, at each clock pulse, the *high* or *low* bit held in each flip-flop is shifted to the next flip-flop (except at the ends). This mode of operation of the shift register, where the bits play follow-the-leader, is called the *serial* mode. Some shift registers, like the one in the Rhythm Synthesizer, can also operate in the *parallel* mode. In this mode the inputs of the flip-flops are disconnected from the outputs so that all the flip-flops can be *loaded* simultaneously from outside during a single clock pulse.

In the R&B Box, IC's 5, 6, and 7, each a four-bit shift register, are cascaded to form a 12-bit shift register.



Just by properly setting the controls, you can program our Rhythm and Blues box for any kind of beat you might want to tap your toes to. Any sequence of one to twelve beats, with any of the individual beats accented, is readily set.

As described later, to start a rhythmic pattern the shift register is loaded in the parallel mode with a *high* in stage 1 and *lows* in the remaining 11 stages. The shift register is then put into the serial mode and clocked by the positive clock pulses from pin 4of IC3D, which shift the single *high* from stage to stage (left-to-right in the circuit diagram). Thus the otuput of each stage goes *high* in sequence. This continues until the *high* reaches the stage selected by the *Sequence Length* switch, S3. S3 then feeds the *high* to the input of a *D-type* flip-flop (pin 9 of IC4).

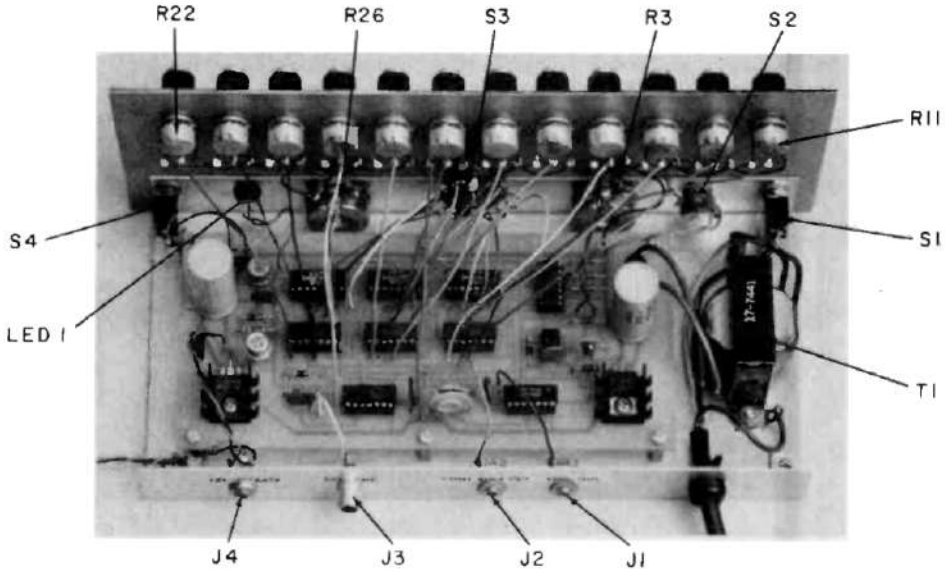
A D-type flip-flop has the characteristic that the logic level (*high* or *low*) present at its input before it is clocked will be assumed by its output after it is clocked. However, note that the clock input (pin 11 of IC4) of the D flip-flop is fed the inverted clock pulse from pin 3 of IC3C. So when the shift register is being clocked by the rising edge of the positive clock pulse, and the *high* is fed to the D flip-flop input, the D flip-flop sees the falling edge of the inverted clock pulse and just sits there with its output still *low*. A few milliseconds later, at the end of the clock pulse, the D flip-flop is clocked and then the *high* is transferred to its output (pin 13 of IC4), which connects to the load enable input of the shift register (pin 7 of IC5, 6, and 7). This puts the shift register into the parallel mode. Nothing happens until the next clock pulse, at the beginning of which the shift register is loaded with a *high* in stage 1 and *lows* in the other stages, and at the end of which the output of the D flip-flop goes low, putting the shift register back into the serial mode. The situation is now the same as it was when we began our analysis, and the whole sequence repeats.

Here we have been assuming that S3 is set to a number (2–12), causing the shift register to keep reloading automatically as described, so that the sequence repeats indefinitely. However, if *Sequence Length* is set to *off*, the *high* in the shift register is shifted through all 12 stages and out the end without being fed to the D flip-flop, so the shift register is not automatically re-loaded. Thus the sequence only occurs once, after which the R&B Box quiets down. To start the action again, it must be loaded manually.

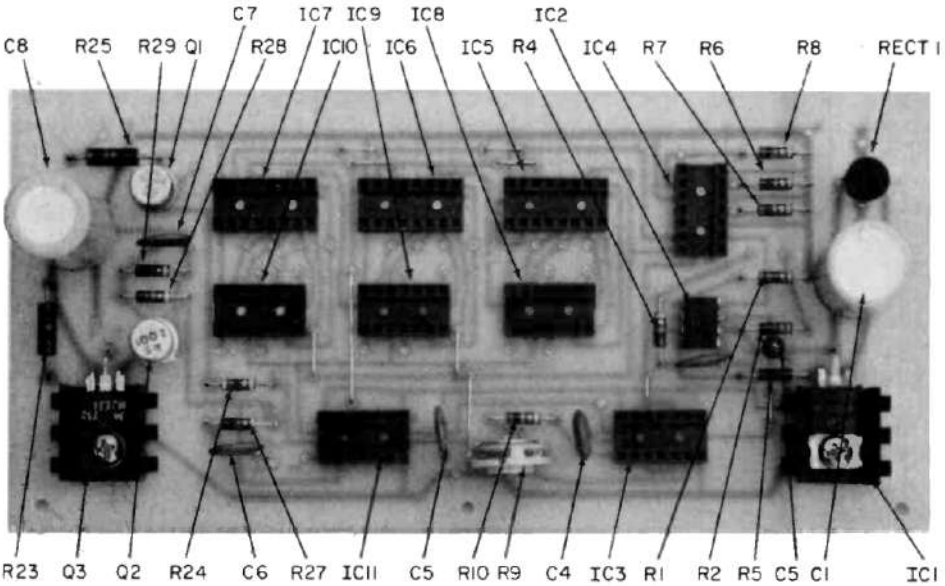
The shift register is loaded manually by means of the *Reset/Start* pushbutton, switch S2, and the other half of IC4. This half of IC4 is also a D-type flip-flop but is used here as a *set-reset* flip-flop or *bistable latch* to eliminate the effects of switch bounce from S2. Pushing S2 makes pin 6 of IC4 *high*, *setting* the latch. This in turn sets the other flip-flop (via pin 1 to pin 8) in IC4, which puts a *high* on the load enable input of the shift register (pin 7 of IC5, 6, and 7), putting it into the parallel mode. At the same time, the latch makes pin 4 of IC2 *low*, stopping the tempo pulse to keep the synthesizer silent.

Releasing S2 makes pin 4 of IC4 *high*, which *resets* the latch, and IC2 and IC3 start producing pulses. The initial pulse first clocks the shift register, loading it, and then clocks the D flip-flop so its output goes *low*, putting the shift register into the serial mode. After that the *high* in the shift register is clocked from stage to stage as described previously.

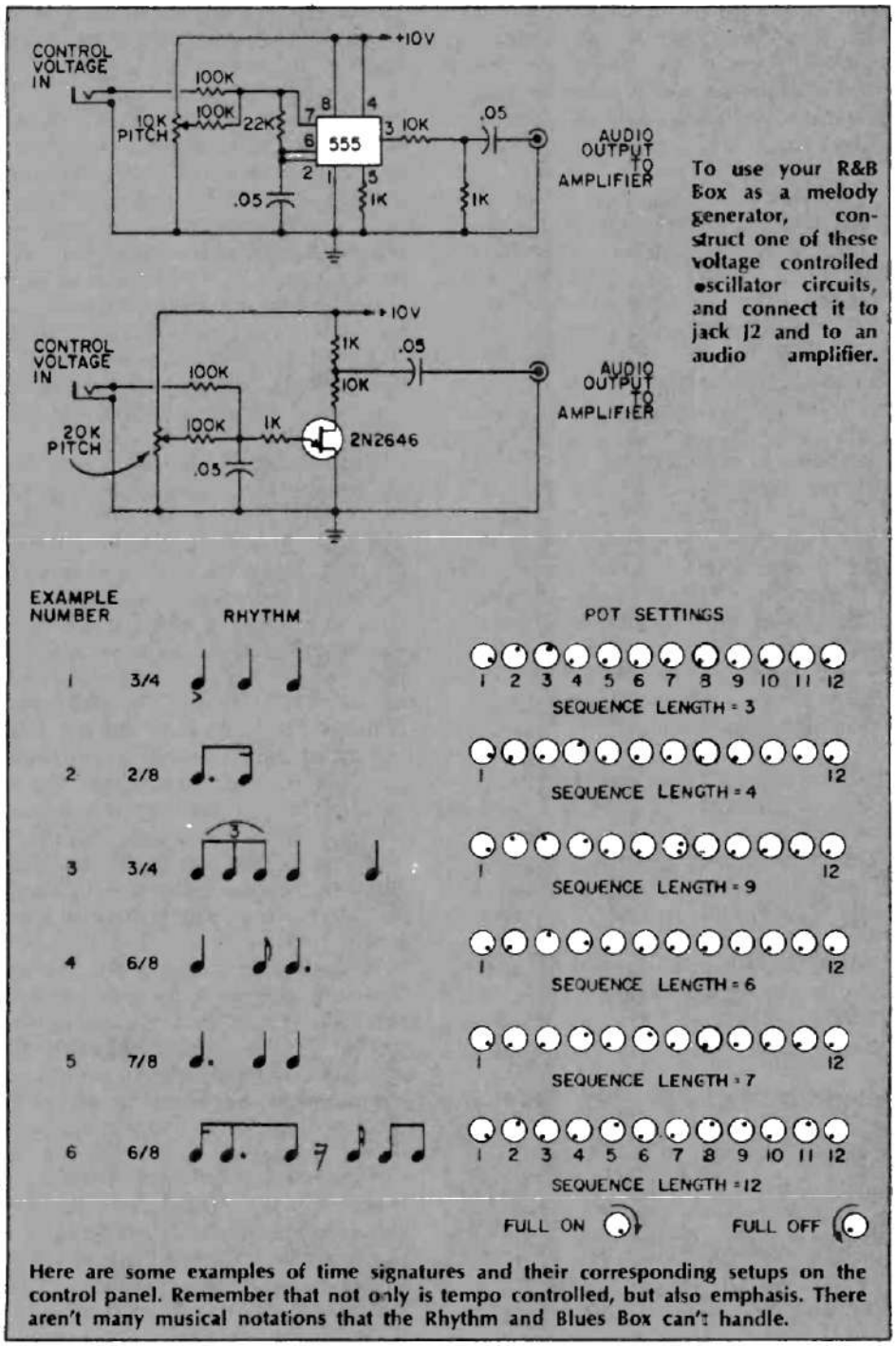
Move To Multiplexing. Let's move on to the next section of the circuit to see why the *high* is being shifted around. The output of each stage of the shift register is fed to the control input of an *analog switch* (in IC8, 9, and 10). An analog switch is a solid state ver-



With the cover removed, the placement of all components can be observed. When wiring the front panel pots, it's a good idea to tag the wires from the PC board for identification. For more work room, install only every other pot at first, wire, then install the rest.



A neat, clean, professional printed circuit board can be made using the free template available from e/e. To obtain one, send a stamped, self-addressed envelope to: Rhythm & Blues Box, ELEMENTARY ELECTRONICS, 380 Lexington Ave., N.Y., NY 10017.



To use your R&B Box as a melody generator, construct one of these voltage controlled oscillator circuits, and connect it to jack J2 and to an audio amplifier.

Here are some examples of time signatures and their corresponding setups on the control panel. Remember that not only is tempo controlled, but also emphasis. There aren't many musical notations that the Rhythm and Blues Box can't handle.

sion of a relay; when the control input is *high* the two signal lines are connected together with a low resistance; when it is *low* they are disconnected. An analog switch differs from a logic gate in that a logic gate deals only in *highs* and *lows*, whereas an analog switch passes any voltage level (within limits), and passes it in either direction.

At the beginning of a rhythmic sequence, the *high* in stage 1 of the shift register turns on the first analog switch (pins 1 and 2 of IC8 are connected), while the remaining switches are off. At this time the common output line of the analog switches (pins 2, 10, 3, and 9 of each of the chips IC8, 9, and 10) is connected only to the wiper of pot #1 (R11) and assumes the voltage level set by that pot. At the next clock pulse the *high* shifts to stage 2 of the shift register, which turns on the second analog switch, while all others are off. The output line is now connected to the wiper of pot #2 (R12), and so on down the line. As the shift register goes through its sequence, a sequence of voltage levels that correspond to the settings of the numbered pots appears on the common line.

This type of circuit, where a common line is connected to a series of inputs (or outputs) one at a time in sequence is called a *multiplexer*.

On To The Output. The last stop on our tour is the output section, where the voltage levels from the multiplexer are converted into loudness levels of audible clicks and into brightnss levels of LED flashes. The voltage levels are gated through two more analog switches (in IC11), one for the clicks, one for the flashes. We'll see how the clicks are produced first.

The sequence of voltage levels is fed into a signal input of one of the switches (pin 8 of IC11). This switch is turned on briefly during each voltage level by the clock pulses from pin 4 of IC3D. Coming out of the switch (pin 9 of IC11) is a sequence of short pulses whose amplitudes are the same as the voltage levels from the multiplexer, which in turn correspond to the settings of the numbered pots. An amplifier consisting of Q2, Q3, and associated components gives the pulses sufficient current to drive the speaker, producing a sequence of clicks. The loudness of each click in the sequence corresponds to its pot setting.

A similar arrangement is used to drive the LED, with another analog switch (pins 10, 11, and 12 of IC11) and Q1. In this case the analog switch is turned on by pulses directly from IC2 (pin 3), which are longer than the clock pulses from IC3. If the shorter clock pulses were used, the LED flashes would be too brief and dim.

Pins from the two unused switches in IC11 (pins 1 to 5 and 13) are tied (as indicated in the schematic) to convenient points to keep them from picking up stray signals.

Power for all the above is provided by a regulated power supply of conventional design, consisting of T1, RECT1, C1, and IC1. R5-C3, C5, and R23-C8 isolate the power lines to IC2 and to the output section from the rest of the circuit to prevent undesirable interactions.

Getting It Together. Although it involves a fair amount of wiring, there is nothing particularly difficult about assembling the Rhythm & Blues Box. Follow the directions given here and the diagrams and photos and you shouldn't have any trouble. If this is one of your first projects, enlist the help of someone experienced in electronic construction.

When assembling the rhythm synthesizer, keep in mind that CMOS IC's (IC3 through IC11) can be damaged by static electricity or other excessive voltages, so handle them appropriately.

Leave them in their packages until the final steps of construction, as described later.

Although the R&B Box could be hand wired, a printed circuit (PC) board will make the job easier and the finished product neater. An actual-size PC etching guide is provided. Most of the components of the synthesizer mount on the PC board, as shown in the parts placement diagram. Note that ten jumper wires are required (identified by J). These are all inserted from the component side of the board and may be bare wire. Use sockets for the nine CMOS IC's; using a socket for IC2 is optional. Heat sinks are recommended for IC1 and Q3, either commercial or homemade from a scrap of metal.

The optimum value for R28 depends on the particular transistors used for Q2 and Q3 and on the speaker. You will want to determine its optimum value as described later, so, do not install R28 at this time; in its place temporarily wire a 100 K pot in series with a 10 K fixed resistor. Set the pot approximately at midrange.

After assembling the PC board, check carefully for solder bridges, bad connections, etc. The PC board may be mounted to the chassis or cabinet by means of six sets of screws and spacers at the location indicated near its edges.

Arrangement of the components off the PC board is not critical. The author's arrangement is shown in the photos. Some of the connections from the PC board to these components are indicated by circles on the schematic diagram. Letters within these circles also appear on the etching guide.

If you use the switch specified in the parts list for S3, you will need to make a simple modification to it. The specified switch has a rotation stop which allows only eleven positions to be indexed. Bend the stop out of the way to allow all twelve positions to be indexed. Note that in the newly-created position the switch rotor does not contact any of the stationary treminals; this position is used as the *off* position. When wiring switch S3 and pots R11 through R22, take care to connect the wires in the correct order. Note that S3 is wired only to stages 2 through 12 of the shift register. The chassis, panel, and cabinet were custom made for the author's unit, but standard commercial items could be used. The author's cabinet measures 4-in. high by 10½-in. wide by 5-in. deep.

Tuning Up. After you have completed the wiring and assembly, but *before* you insert the CMOS IC's, check out the power supply. Plug the unit in, switch it on, and measure the voltage between the point labeled P and either one of the points labeled G on the PC board. It should be 10 volts (plus or minus 0.1 volt) with P positive. If not, check the power supply (S1, T1, RECT1, C1, IC1) for wiring errors or faulty parts. When the power supply checks out, unplug the R&B Box and insert the IC's, observing their orientations.

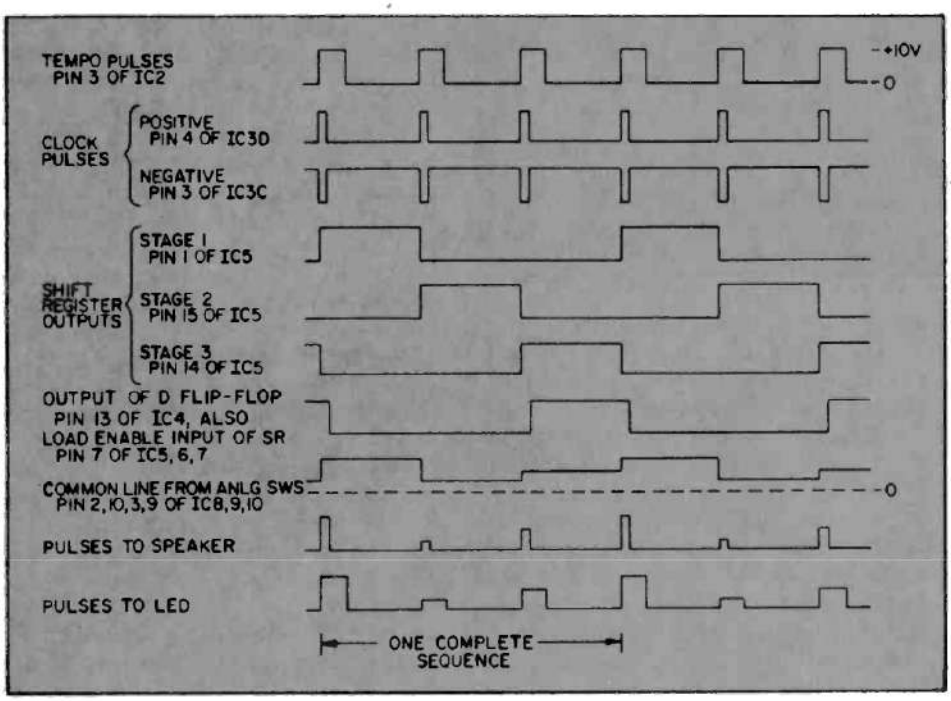
To continue the checkout, set the controls as follows: pots #1 through #12 fully clockwise; *Tempo* about ¼ of the way clockwise; *Sequence Length* to 12; *Volume* fully clockwise; *Light* to *on*. Turn the power on and push and release *Reset/Start*. Immediately after it is released, a continuous series of clicks should be heard (actually the synthesizer may start without pushing *Reset/Start*). The clicks should all be equally loud, at evenly-spaced intervals, and the LED should flash for each click.

Sour Notes? If your R&B Box doesn't behave as it should, first recheck the PC board and all wiring. Make sure the IC's are properly installed and oriented. Next, try to determine which indicates that the clock (IC2 and IC3) is working. Check for a series of 10-volt pulses at the *External Amplifier* jack, which indicates that the shift register (IC5, 6, and 7) and analog switches (IC8, 9, and 10) are working. If either the sound or light operates, but not the other, check the appropriate output circuitry. If one of the clicks is weak or absent, look for a problem in the corresponding stage. The troublesome stage can be identified by varying each numbered pot in turn.

Assuming everything is OK, the next step is to determine the optimum value for R28. Verify that all controls are set as specified earlier; be sure that *Volume* is at maximum. If you can get an oscilloscope, connect it across the speaker terminals to observe the pulses; if not, make the adjustment by ear. First set the 100 K pot (which you temporarily wired in place of R28) for maximum resistance. Turn the synthesizer on and start it pulsing. Now, slowly decrease the resistance of the pot, which should cause the amplitude of the pulses to increase up to point of saturation—in other words, a point where the amplitude of the pulses no longer increases with a further decrease of the pot's resistance. Back the pot off slightly from this point and, without disturbing its setting, unplug the synthesizer and remove IC11. Measure the combined resistance of the pot and 10 K resistor, and install in their place a fixed resistor of the same value (or the nearest standard value).

Reinsert IC11, start the R&B Box again and continue the checkout by turning all the numbered pots except #1 down to about ⅛. This should result in one loud click (corresponding to pot

(Continued on page 88)



Need an adjustable waveform generator? The Rhythm and Blues Box can handle that too. Simply tap in at the appropriate point, hook up your scope, and you're ready to go.

BNEE

(Continued from page 66)

or a set of paddles—one for dits and one for dahs—with separate electronics), or a "bug" is pretty much up to you and what you feel most comfortable in using.

If you elect to go with an electronic keyer, make sure the output of the keyer is compatible with the keying circuit of the transmitter. Read the manuals carefully! An improper connection or too much voltage on the switching transistor in the keyer's electronics will lead to an early repair job, and some warranties don't cover owner abuse.

What do *I* use? A straight key . . . but one of these days I'll get around to working with an electronic keyer.

In Closing. Next time we'll talk about sending and receiving code, and review some basic operating practices. In advance of this discussion, you may wish to order some supplemental material.

The *American Radio Relay League, 225 Main St., Newington, CT 06111,* will supply the following operating aids free of charge: (1) CD 5/9 W1AW Schedule; (2) CD-139 Current On-the-Air Code Practice Stations; (3) CD-220 The R-S-T System/Time Conversion; and (4) CD-218 Amateur Message Form. Also ask for an order blank for the ARRL Logbook.

Although the Operating Aids are not required for an understanding of our upcoming discussion, each aid has some useful information that will probably be of interest to you. ■

Rhythm & Blues

(Continued from page 33)

#1) followed by eleven softer ones (corresponding to pots #2 through #12). The brightness of the LED flashes should follow the same pattern. Holding the *Reset/Start* button in should stop the clicks. Releasing it should immediately start the sequence of clicks again, beginning with #1, the loudest. Now set *Sequence Length* to 11; a repeating sequence of one loud click followed by ten softer ones should be heard. Similarly check *Sequence Length* settings of 10, 9, 8, etc. When changing the *Sequence Length* setting the pulse may be "lost" from the shift register with the result that the clicks are no longer produced. This is normal, and if it happens, simply push and release *Reset/Start* to restore operation. With *Sequence Length* at *off*, a sequence of twelve clicks should be produced (the first one should be loudest) each time *Reset/Start* is pushed and released.

Check that the loudness of each of the twelve clicks in the sequence can be varied from zero to maximum by adjusting the corresponding pot. The brightness of the LED flashes should also correspond approximately to the pot settings. Finally, adjust trimpot R9 ot give the desired sound quality to the clicks.

Performance. After going through the circuit description and checkout you should have a general idea of what the synthesizer does. To use it, decide how many beats or pots you need for your rhythm: this will be the *Sequence Length* setting. Then turn the appropriate numbered pot up to emphasize a beat, down to de-emphasize it, or off to delete it.

As you have seen, the R&B Box can operate in two modes, either *single-shot* or *continuous.*

For the *single-shot* mode set *Sequence Length* to *off.* In this mode a sequence of all twelve clicks is produced each time *Reset/Start* is pushed and released. The sequence always begins from the left with pot #1. If fewer than 12 pots are needed in this mode, turn the unused pots (on the right) completely off to prevent unwanted clicks following the end of the rhythmic pattern.

For the *continuous* mode set *Sequence Length* to one of the numbers (2 through 12) as required for your particular rhythm. The pot with that number will be the last one in the sequence. The sequence will repeat indefinitely once it is started by pushing and releasing *Reset/Start.* In this mode the settings of the unused pots on the right do not matter; otherwise, operation is the same as in the *single-shot* mode.

The fastest way to become familiar with the Rhythm & Blues Box is to experiment with all the controls. There is no way you can damage it by experimenting, so don't be timid.

Examples of how to set up various rhythms are shown in the pictorial. For these examples, the initial beat, or downbeat, is louder than the others to identify the beginning of the rhythmic pattern, but this is not mandatory. In fact, none of the pots needs to be set exactly as shown, so feel free to do your own thing.

Example #1 is a simple "waltz" rhythm with three beats: LOUD-soft-soft. Set SEQUENCE LENGTH to 3, pot #1 fully on (clockwise), pots #2 and #3 about halfway up as shown. *Tempo, Volume* and *Light* may be set as desired. In a similar way you can set up rhythms of 2, 4, 5, 6, etc. beats with the first beat emphasized.

Example #2, a "dotted" rhythm, has two notes of unequal duration; the first (dotted eighth) is three times as long as the second (sixteenth). The shortest time unit in the pattern is a sixteenth and the total length of the pattern is four times this (2/8 or 4/16). Consequently, *Sequence Length* should be set to 4. Pot #1 should be fully on, pot #4 about halfway, pots #2 and #3 fully off. For this rhythm, clicks #2 and #3 are deleted. As illustrated by this example, a rule of thumb is that the *Sequence Length* setting should equal the total length of the pattern divided by the shortest time unit.

Example #3 begins with a "triplet", whose note each have a time value of 1/12; the total pattern has a time value 3/4 or 9/12. Thus a *Sequence Length* of 9 is used.

Example #4 is a common rhythm and is a straightforward set up on the Synthesizer.

Example #5 is an uneven rhythm typical of Eastern music. Such rhythms are frequently troublesome, but are easily handled with our rhythm synthesizer. If you need to analyze such rhythms it may be helpful to turn on the "silent" beats slightly; in this example #2, 3, 5, and 7.

The final example, #6, illustrates how the synthesizer can accommodate fairly complex rhythms. All twelve pots are needed since the smallest time unit is a 1/16 note and the total pattern duration is 6/8 or 12/16.

Off-Beat Uses. As mentioned at the beginning, the rhythm synthesizer is also useful as a programmable controller for electronic music synthesizers and other equipment. The *Control Voltage Out* jack (J2) puts out a sequence of voltage levels corresponding to the settings of the numbered pots.

For example, the sequence of voltage levels can be fed to a VCO (voltage controlled oscillator) to generate programmed melodies of up to twelve notes. If you want to try this, two simple VCO circuits which can be controlled in this way by the rhythm synthesizer are given in the figure.

You can also use the R&B Box as a waveform generator for square, pulse, staircase, and other waveforms, again by using the signal from the *Control Voltage Out* jack. To get an idea of the possibilities, connect an oscilloscope set at a slow sweep rate to J2, turn *Tempo* all the way up, set *Sequence Length* to 12, and vary the numbered pots.

In case you want to run your rhythms through another amplifier or speaker, an *External Amplifier* jack (J3) and *External Speaker* jack (J4) are provided.

Get into the swing of things with our Rhythm and Blues Box and be the most percussive constructionist who ever drummed up a storm! ■